REQ. NO. 9-9071

CONTRACT REPORT NO. OSQ79-00139

DEVELOPMENT OF A PROTOTYPE HIGH ENERGY DIESEL EXHAUST SCRUBBER SYSTEM.

FINAL REPORT (DSS # 18SQ.23440-9-9071)

FOR CANMET, ENERGY MINES AND RESOURCES CANADA

OTTAWA, ONTARIO

CONTRACTOR: JARVIS CLARK CO. LTD.

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ATTACHED DRAWINGS	DRAWING NO.
1. Venturi Scrubber Weldment	Item #1
2. L.H. Tank Weldment	Item #2
3. R.H. Tank Weldment	Item #3
4. Exhaust Weldment	Item #4
5. Hyd. Motor-Water Pump Mount	Item #9
6. Venturi Mount	Item #10
7. Design Layout	Item #A

ABSTRACT

This report describes the following:

1. Design feasibility study of a high energy venturi scrubber exhaust system installation on a JS-500 equipped with an F8L-413 Deutz Engine.
2. Selection of optimum design configuration and components.
3. Preparation of a drawing package for manufacture and performance evaluation of system.

The above work was done under contract with Canmet as the first step in the practical application of theories developed by Canmet and directed towards the reduction of exhaust particulates produced by diesel-powered mining equipment by means of a high energy venturi scrubber system.

William H. Bricknell
Programme Manager
Jarvis Clark Co. Ltd.
North Bay, Ontario

A. Branje
Designer
Jarvis Clark Co. Ltd.
North Bay, Ontario

INTRODUCTION

With a growing recognition of the health hazard imposed by diesel particulates, regulations limiting their emissions are to be anticipated. At this time, a preliminary draft of the certification manual for diesel-powered mining machines stipulates a level of particulate in the mining atmosphere (Health Effects Index) which is considerably less than the present level.

Anticipating future reduced levels of particulates in the mining atmosphere, Canmet and various research facilities are currently investigating alternate systems which will meet future regulatory levels. One of these systems is the high energy diesel exhaust scrubber system. Since the feasibility of the system is dependent on finding space for all the components in an inherently compact machine, it was felt that the machine manufacturer should do the design feasibility study and prepare detail drawings for the prototype build.

SYSTEM CONFIGURATION DETERMINATION

The following design parameters were established as design guides for optimum system configuration, several of which were considered before selecting one as the basis for further design work.

1. Water capacity of 90 gallons minimum.
2. Minimum frame rework.
3. Maximum simplicity.
4. Serviceability.

The selected configuration, which is illustrated in FIGURE 1, permitted the following:

1. Simple tank design of preferred capacity (180 gallons) illustrated in drawings Item #2 & #3.
2. No change in rear hood profile or reduction in visibility.
3. Exhaust gases could exit from mist eliminator through standard opening in frame.

4. Simplified serviceable piping.

It should be noted that electric start in place of the standard air start is mandatory. There is insufficient space for a large air storage tank normally located in the skirt area for engine start and braking. A smaller air tank is located elsewhere for braking.

VENTURI SCRUBBER DESIGN

Since Canmet had specified the internal dimensions of the scrubber, only two considerations remained:

1. Material selection.
2. Configuration for manufacturing purposes.

1. AISI 316L stainless steel, being readily available, machinable, and resistant to hot sulfurous gases, was chosen as the scrubber material.

2. Jarvis Clark's Manufacturing Methods Dept. favoured the welding together of 3 machined sections. The venturi was designed accordingly as illustrated in drawing Item #1.

WATER PUMP SUPPLY SYSTEM

A detailed schematic of the supply system is shown in FIGURE 7, and its design and operation are summarized as follows.
The required water supply, proportional to engine r.p.m., is provided by a hydraulic pump/motor system, coupled to a water pump. An engine driven hydraulic pump drives a hydraulic motor which is coupled to a water pump.

Having determined the supply pressure equal to 177 p.s.i. @ 0.37 g.p.m. per nozzle (See Appendix 1), a water pump was selected to meet these requirements. By appropriate sizing of the hydraulic pump and motor, the water pump is driven at 1800 r.p.m. and delivers 1.5 g.p.m. The tabulated values in FIGURE 8 indicate that a Deutz 5.8 g.p.m. pump and a Parker H31 motor coupled with a Hypro 5315 pump will supply the required 1.5 g.p.m.

MIST ELIMINATOR DESIGN

Of several eliminator manufacturers contacted, only Munters-Euroform would supply us with a unit that would suit our application and fit our anticipated time frame.

After supplying Munters with the system specifications, they responded with two choices. The model T-271-K vertical flow eliminator was chosen as the most suitable eliminator. FIGURES 9 and 10 illustrate the quote and description of the T-271-K eliminator.

WATER TANK DESIGN

The tanks were designed to bolt easily into the fender skirts. Since a common grade of steel (HRS. CSA G-40.21-33W) was chosen as the manufacturing material, the interior of the tanks will be coated with a waterproofing compound to prevent rusting of the interior walls.

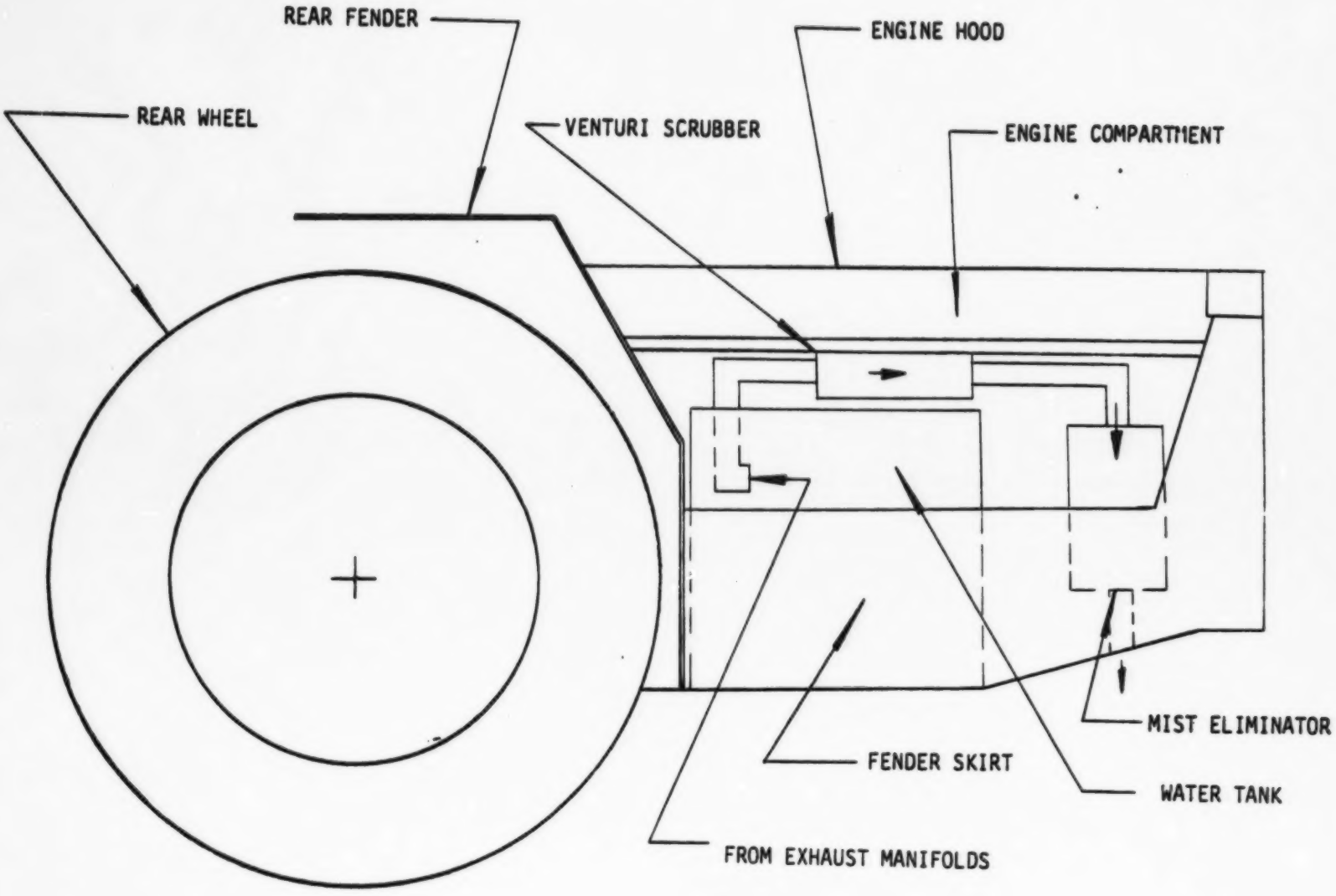
CONCLUSION

1. The JS-500 LHD can accommodate a high energy venturi scrubber type exhaust system with a water reserve capacity of approx. 180 gallons as designed and detailed in the accompanying drawings.

2. A mist eliminator is available from Munters-Euroform which would suit this application. Installation drawings will be supplied approximately 1 month after receipt of an order.

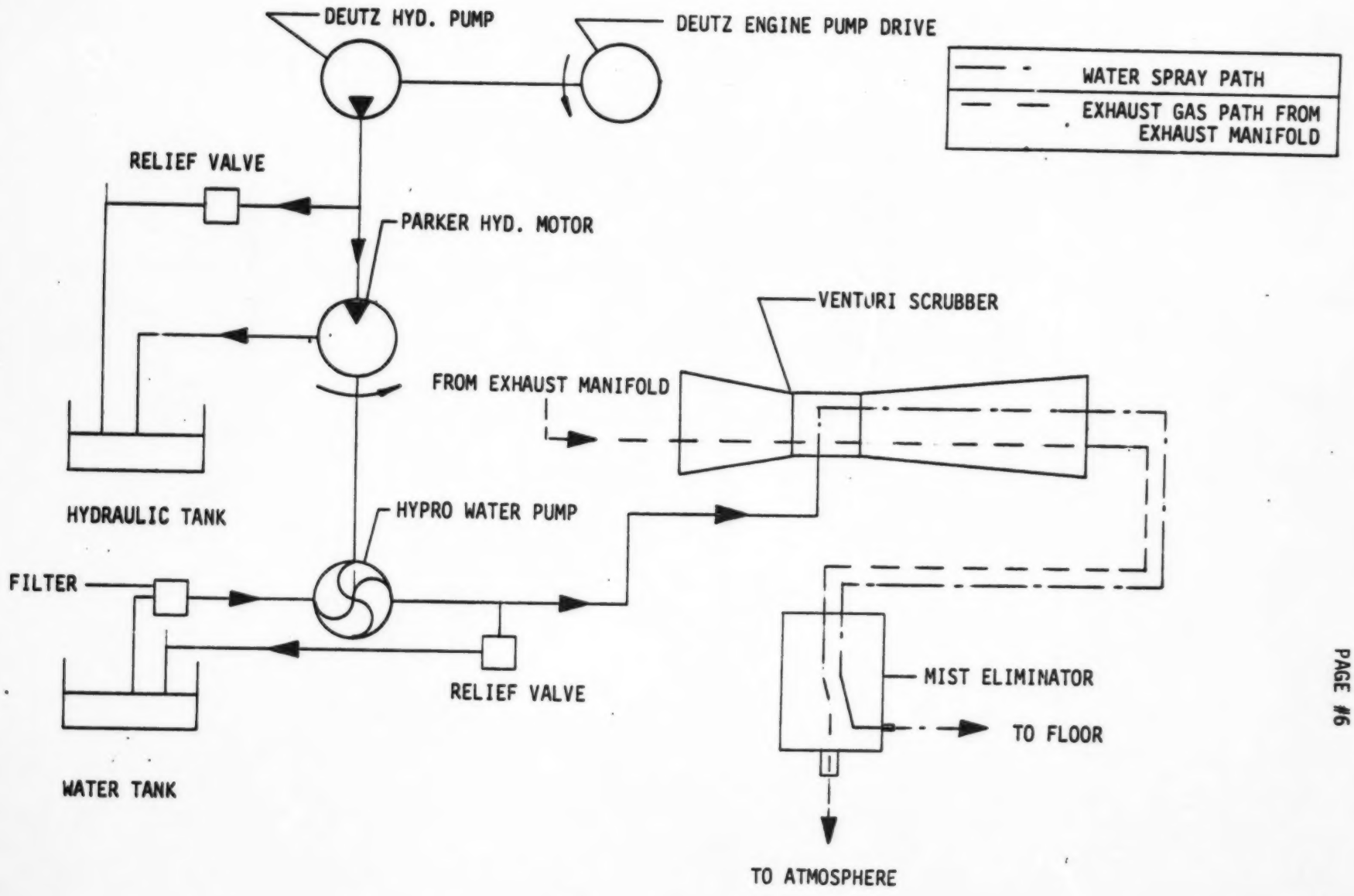
3. A water supply system proportional to engine speed which supplies approximately 1.5 g.p.m. at 2300 r.p.m. (max. engine speed) was designed. This may be adjusted by changing the displacement of the hyd. pump, hyd. motor or water pump.

FIGURE 1



SYSTEM CONFIGURATION PROPOSAL NO. 1

FIGURE 2



SCHEMATIC OF HIGH ENERGY DIESEL EXHAUST SCRUBBER SYSTEM

FIGURE 3

DEUTZ PUMP FLOWRATE

CC/REV. *	GPM @ 2300 RPM ENGINE SPEED **
4.5	3.3
8.0	5.8
11.0	8.0
16.0	11.7

* See Figure 10

** Gear Ratio of 1:1.2

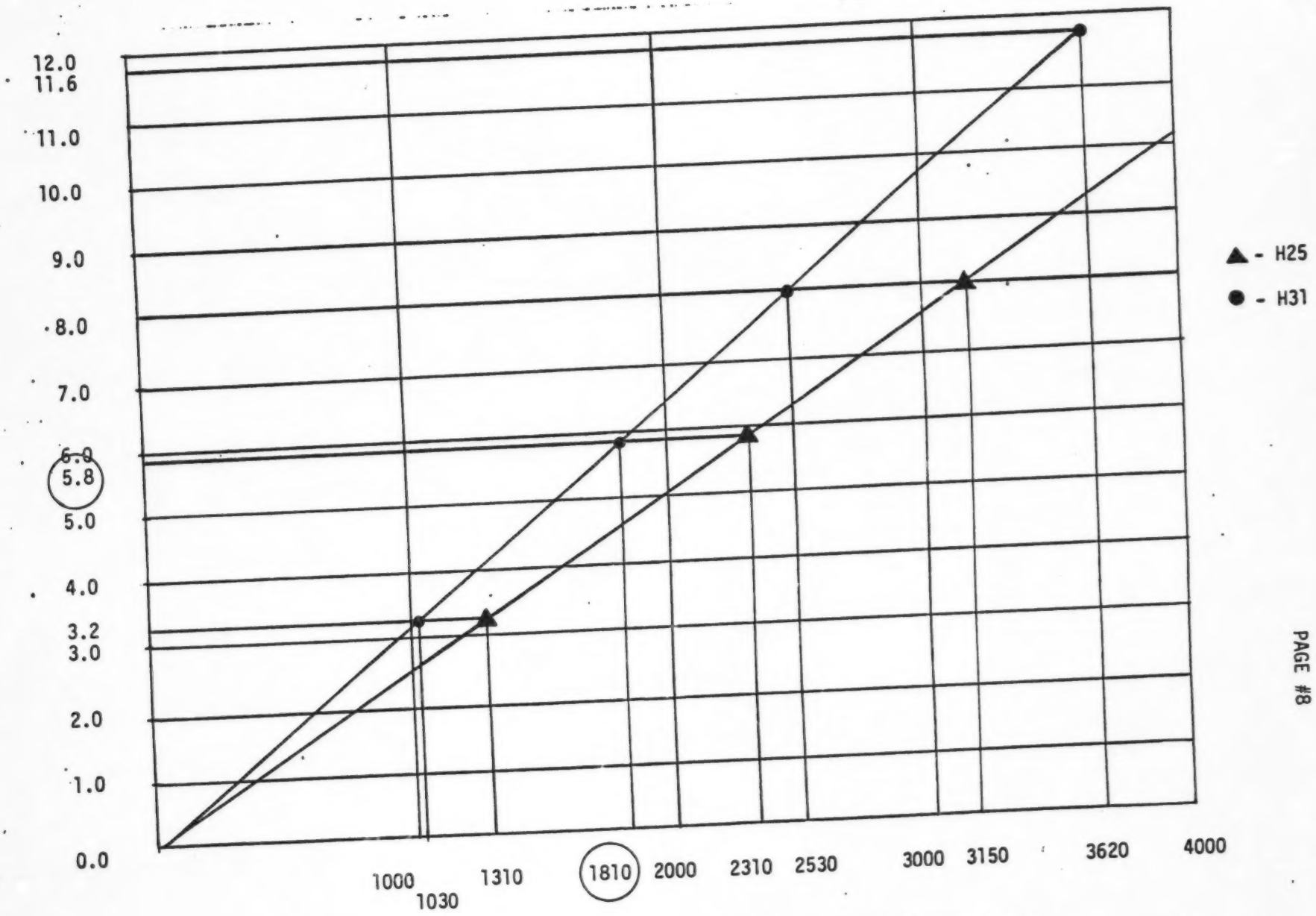
DEUTZ PUMP FLOWRATE VS. PARKER MOTOR SPEED FROM FIGURE

MOTOR SPEED / PUMP FLOWRATE	H25 ***	H31
3.3	1310	1030
5.8	2310	1810
8.0	3150	2530
11.7	+	3620

*** See Figure 11

\+ Exceeded 4000 RPM

FIGURE 4



PLOTS OF DEUTZ PUMP FLOWRATES VS. PARKER MOTOR SPEEDS

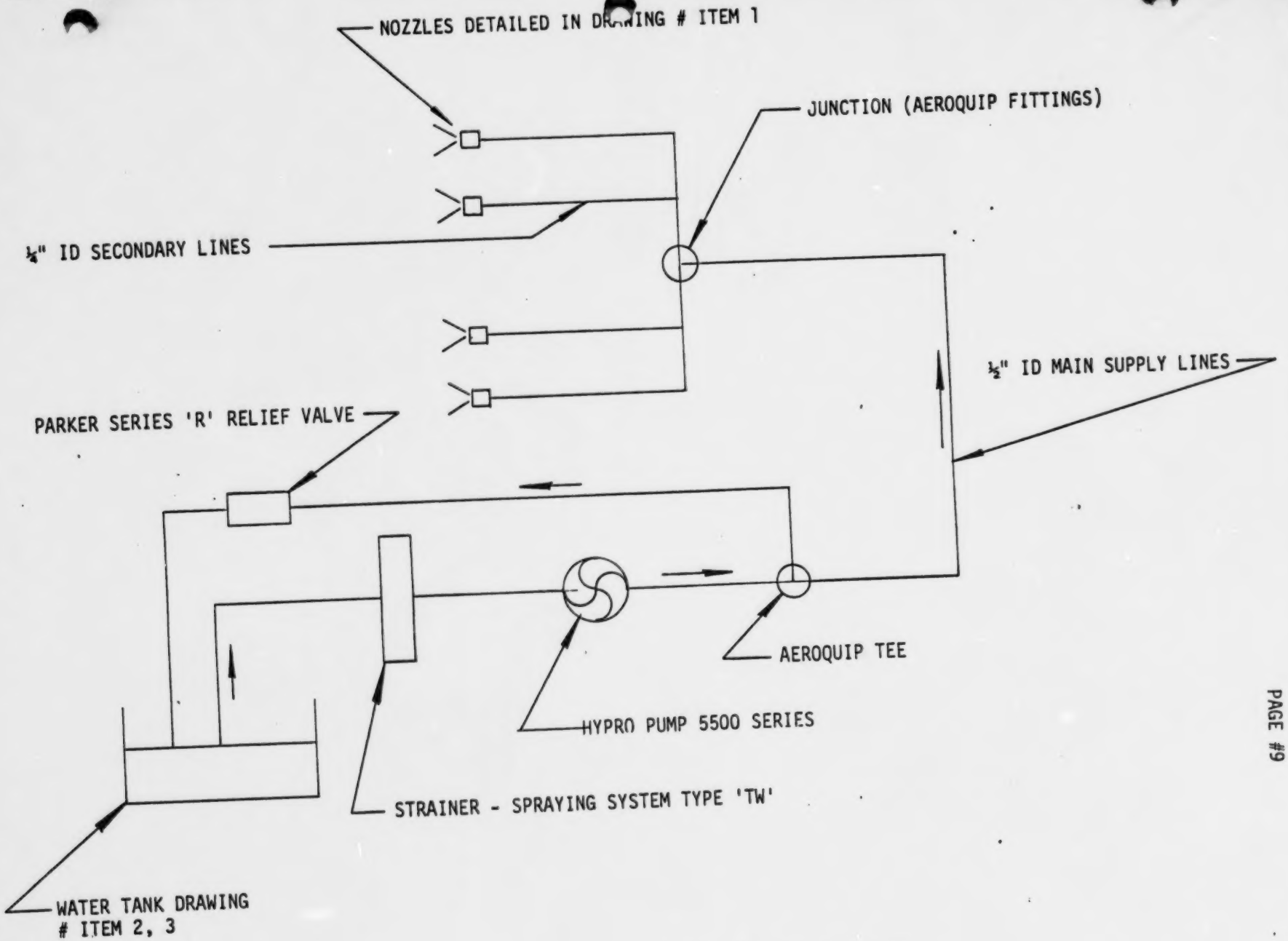

NOZZLES DETAILED IN DRAWING # ITEM 1
JUNCTION (AEROQUIP FITTINGS)
¼" ID SECONDARY LINES
½" ID MAIN SUPPLY LINES
PARKER SERIES 'R' RELIEF VALVE
AEROQUIP TEE
HYPRO PUMP 5500 SERIES
STRAINER - SPRAYING SYSTEM TYPE 'TW'
WATER TANK DRAWING
ITEM 2, 3

FIGURE 5 DETAILED SCHEMATIC OF WATER SUPPLY SYSTEM

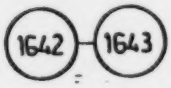
FIGURE 6

Hydraulikpumpe 4,5 ccm/Umdr.
Hydraulic pump 4,5 ccm/rev.
Pompe hydraulique 4,5 ccm/t/mn
Bomba de aceite hidráulico 4,5 ccm/rev.

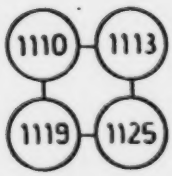
Hydraulikpumpe 8 ccm/Umdr.
Hydraulic pump 8 ccm/rev.
Pompe hydraulique 8 ccm/t/mn
Bomba de aceite hidráulico 8 ccm/rev.

Hydraulikpumpe 11 ccm/Umdr.
Hydraulic pump 11 ccm/rev.
Pompe hydraulique 11 ccm/t/mn
Bomba de aceite hidráulico 11 ccm/rev.

Hydraulikpumpe 16 ccm/Umdr.
Hydraulic pump 16 ccm/rev.
Pompe hydraulique 16 ccm/t/mn
Bomba de aceite hidráulico 16 ccm/rev.



Anbauteile für Hydraulikpumpe
Mounting parts for hydraulic pump
Piéces de montage pour pompe hydraulique
Piezas de montaje para bomba de aceite hidráulico



Kurbelgehäuse-Oberteil
Cranke upper part
Carter supérieur
Carter superior

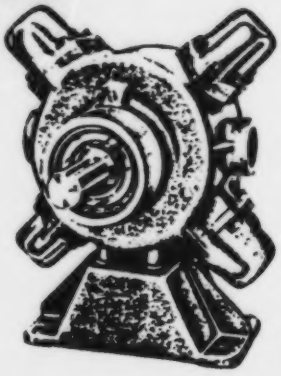
Nebenstromfeinfilter
Partial-flow fine filter
Filtre fin en dérivation
Microfiltro en la corriente secundaria
[illegible]

DEUTZ HYDRAULIC PUMP DESCRIPTION

(DEUTZ DWG. # 324 7912 UA 0148-97/2)

FIGURE 7

5400



High pressure, high volume, four cylinder pumps.

Output to 25 gpm — Pressures to 600 psi — Speeds to 600 rpm

Series 5400 pumps have the force and capacity to be effective in spraying the tops of orchard and shade trees, in throwing a full stream of water for efficient fire fighting, or in high-pressure car and equipment washing. Four individually removable cylinder heads provide quick, easy access to valve and piston parts without disconnecting pump from power source or liquid lines. This is an exceptionally rugged pump for heavy duty service.

Shaft: 1-1/4".
Ports: 1-1/4" NPT.
Bearings: Dual cam bearing construction provides a separate bearing row for each pair of pistons. Shaft is supported by a roller bearing plus a double-row ball bearing.
Horsepower: 1 to 11.25.
Option: Cast-iron base.
See form 181 for complete information.

Model D5412 — for pressures to 1200 psi

This special version of the series 5400 has a shorter stroke and reinforced, ductile iron housing, heads, and connecting rods that enable it to deliver up to 14½ gpm at pressures to 1200 psi when operated at 800 rpm.

Horsepower: Up to 12 hp for maximum pressure.

5500

High-pressure, low-volume, four cylinder pumps.

Output to 4 gpm — Pressures to 800 psi — Speeds to 1800 rpm

Series 5500 pumps are recommended for coin operated car wash systems, industrial power washers, and similar operations. (Not recommended for use with highly abrasive liquids.) Suction valves built into the pistons and discharge valves under the cylinder caps are easily accessible for service. Two piston seal rings in each cylinder maintain high performance and long wear. Four cylinder design minimizes pulsation. Standard pump delivers 4 gpm at 1800 rpm.

Shaft: Choice of 1" solid shaft, 7/8" hollow shaft, 1-1/8" hollow shaft or 28 mm hollow shaft.

Shaft bearings: Main — Double shielded, double-row, ball type. Crank pin — Double row roller type.

Ports: 1/2" NPT.

Horsepower: .28 to 2.3.

See form 183 for complete information.

Performance — piston pumps.

Series	Model	RPM	100 PSI GPM	100 PSI HP	200 GPM	200 HP	400 GPM	400 HP	500 GPM	500 HP	600 GPM	600 HP	800 GPM	800 HP	1000 GPM	1000 HP	1200 GPM	1200 HP
5000	B5041A	1825	4.18	23	4.15	.57	4.09	1.05	4.06	1.28	4.04	1.52	4.0	2.0	3.97	2.48		
5200	5206	600	5.84	.60	5.83	.90	5.80	1.78										
	5210	600	10.35	1.19	10.41	1.59	10.18	2.83										
5300	5315	1800	1.61	.23	1.60	.34	1.55	.57	1.51	.67								
	5320	1800	2.06	.32	2.25	.44	2.21	.66	2.20	.79								
	5321	1750	2.23	.33	2.22	.49	2.22	.77	2.22	.88	2.20	1.04	2.20	1.32	2.15	1.53		
	5325	1800	2.62	.35	2.60	.46	2.56	.67	2.55	.79								
	5330	1800	3.26	.46	3.22	.63	3.12	.94	3.10	1.10								
5400	D5412R	600	11.0	1.32	11.0	1.80	11.0	3.17	11.0	3.94	11.0	4.71	11.0	6.30	11.0	7.71	11.0	8.95
	5425	600	26.3	3.2	26.3	4.8	26.3	8	26.3	9.6	26.3	11.1						
5500	5540	900	2.1	.28	2.1	.42	2	.68	2	.82	2	.95	2	1.2				
		1200	2.8	.41	2.8	.56	2.8	.90	2.8	1.1	2.8	1.2	2.8	1.6				
		1450	3.4	.50	3.4	.67	3.3	1.1	3.3	1.3	3.3	1.5	3.3	2.0				
		1800	4.1	.66	4.1	.85	4.1	1.4	4.0	1.6	4.0	1.8	4.0	2.3				
5800	5820	600	20.0	1.95	19.5	3.30	18.5	5.70	18.5	6.75								

DIMENSIONS (In Inches)

Length	Width	Height	Shaft Height	Shaft Diameter	Port Size NPT*
8¼	6	9 1/32	2 7/16	1	½ NPT
Series 5200 Solid Shaft Models					
5 11/16	6¼	7 13/16	4 5/16	1	¾ NPT
Series 5200 Hollow Shaft Models					
6 5/16	6⅜	7 13/16	4 5/16	PTO	¾ NPT
All Series 5300, 500 psi Solid Shaft Models					
5 13/32	5⅛	6 13/16	3½	⅝	½ NPT
All Series 5300, 500 psi Hollow Shaft Models					
5 13/32	5⅛	5½	2⅝	⅝ (ID)	½ NPT
Solid Shaft 5321					
5 9/16	5⅛	6⅜	3½	⅝	½ NPT
Hollow Shaft 5321					
5 3/16	5⅜	6¼	3⅛	⅝ (ID)	½ NPT
Series 5412					
11 5/16	11	13½	8	1¼	1¼ NPT
Series 5425					
11 1/16	11¼	13⅝ (w/base)	8 (w/base)	1¼	1¼ NPT
Series 5500 Solid Shaft (1" dia.) Models					
6⅛	9½	8¼	4 9/32	1	½ NPT
Series 5500 Hollow Shaft (⅞" dia. Models					
4 7/16	9½	8¼	4 9/32	⅞ (ID)	½ NPT
Series 5500 Hollow Shaft (1⅛" dia.) Models					
4 7/16	9½	8¼	4 9/32	1⅛ (ID)	½ NPT
Series 5500 Hollow Shaft (28 mm dia.) Models					
4 7/16	9½	8¼	4 9/32	28 mm (ID)	½ NPT
7 11/16	9⅛	11	5 11/16	1¼	1¼ NPT

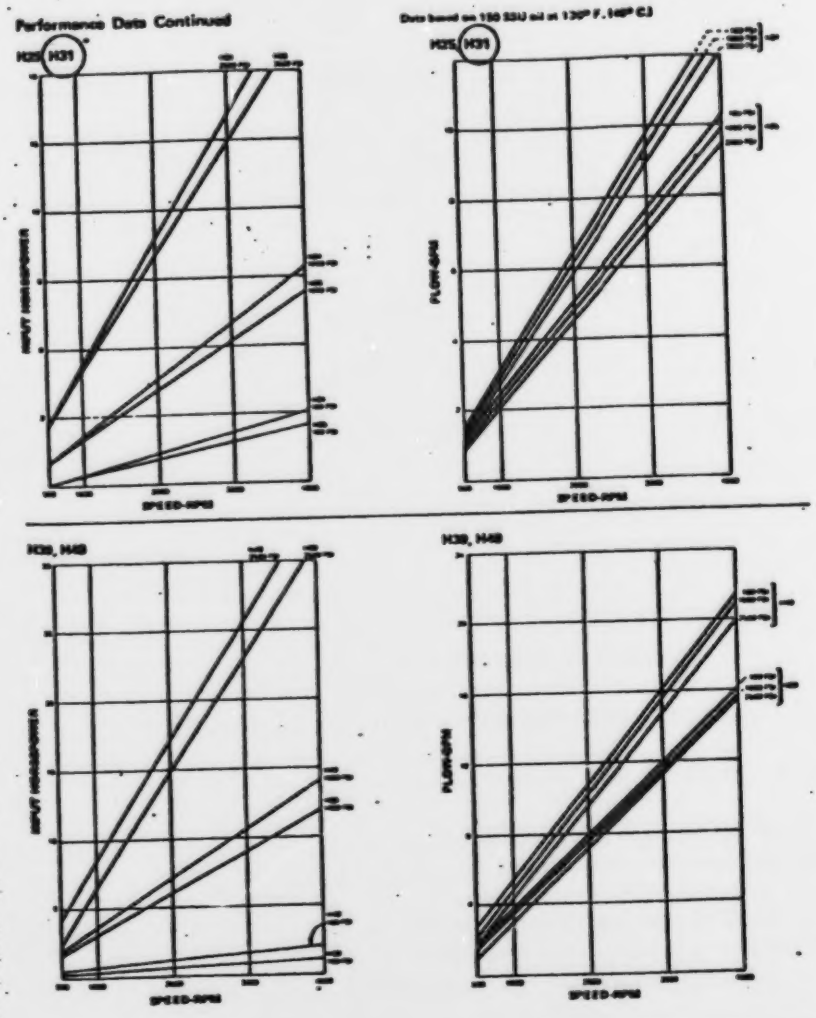
HYPRO WATER PUMP PERFORMANCE VALUES

Fluidpower Components

Parker Fluidpower

Pumps - Fixed Gear
"H" Series

Performance Data Continued



Parker Hannifin Corporation, 17325 Euclid Avenue, Cleveland, OH 44112

FOR *FAST* DELIVERY AND SERVICE
Call your local Parker Fluidpower Distributor

1015

PERFORMANCE CURVES FOR H25, H31 PARKER PUMP/MOTORS

OFFER: EUROFORM MIST ELIMINATORS
for: Jarvis Clark, Ltd.
Project: E-010-1152 - Coal Scrubber, Mobile
Eliminator type: (A) T-271-K
(B) T-125

1/23/80

1.	Operating data:			(A)	(B)
1.1.	Capacity:	acfm	-	400	400
1.2.	Operating temperature:	^{o}F	-	160 max	160 max.
1.3.	Face area:	ft^2	-	.5	.5
1.4.	Face velocity:	fpm	-	800	800
1.5.	Operating pressure:	-	-	-	-
1.6.	Pressure loss:	in. w.c.	-	.15	.3
1.7.	Limit drop:	um	-	40	20
2.	Dimensions each eliminating element:				
2.1.	Height:	in.	-	7.5	18
2.2.	Width:	in.	-	12" circle	9
2.3.	Depth:	in.	-		9
2.4.	Number of elements:	-	-	1	1

3. Price:

3.1. (A).....$70.00 (SEVENTY DOLLARS)

3.2. (B).....$100.00 (ONE HUNDRED DOLLARS)

4. Material: Eliminator vanes and frames: Polypropylene

5. Separation: The separation efficiency is 99% for drops larger than 20 or 40 um guaranteed as shown.

6. Pressure loss: The above stated pressure loss is for the eliminator only and does not include other losses due to turbulence or direction change.

7. Delivery time: Three (3) months from receipt of order and approval of drawing.

8. Quotation: F.O.B. Fort Myers, Florida.
Our offer valid for 60 days.

MUNTERS MIST ELIMINATOR QUOTE

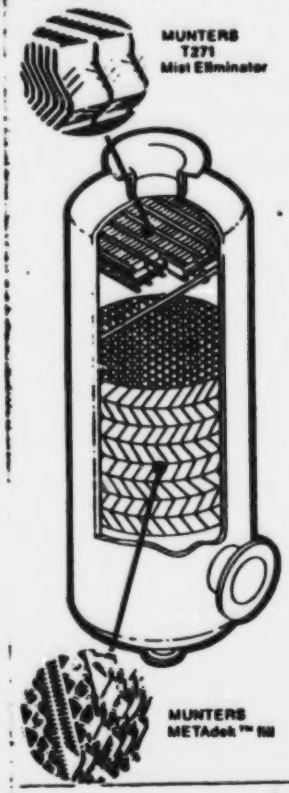
FIGURE 9

Retrofit Advantages

The need for extensive capital investment in equipment is often eliminated because MUNTERS systems substantially increase scrubber efficiency. This eliminates increasing vessel sizes to provide for increased capacity. Modification in existing equipment can be planned and engineered for minimal plant disruption. MUNTERS retrofit systems can be installed at a fraction of the cost of new equipment.

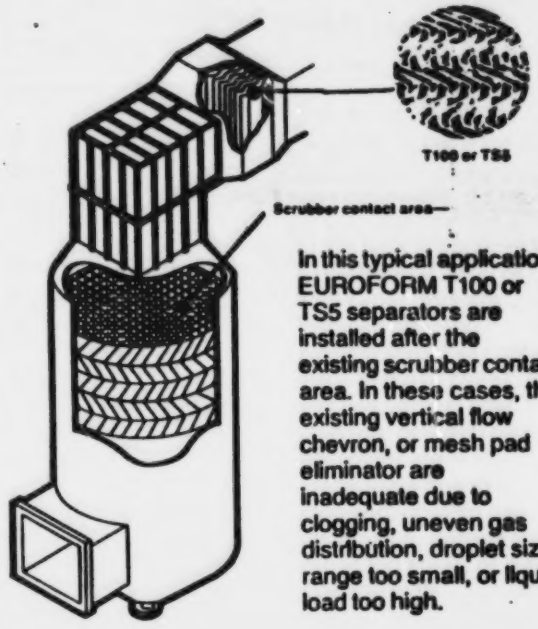
Types of Retrofit

Vertical flow types



Vertical flow eliminators for scrubbers are applied in such applications as recovery boilers in the pulp and paper industry, chemical process absorbers and fertilizer processing, as well as those applications where clogging is a common problem. In this illustration, MUNTERS T271 or T8 separators are being used in combination with MUNTERS fill. The higher permissible velocity of MUNTERS eliminators compensates for poor flow distribution in existing scrubbers.

Horizontal (cross flow) types



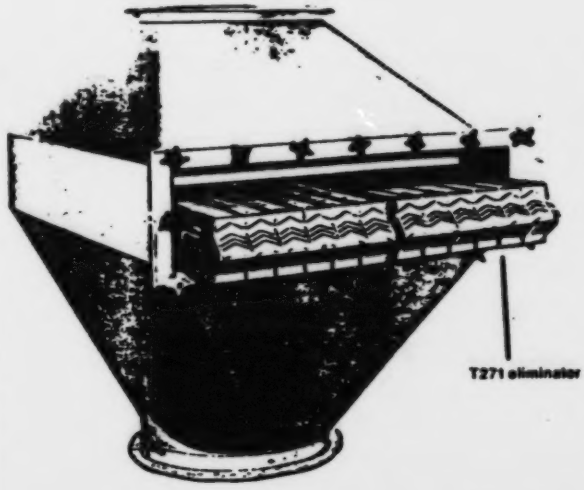
In this typical application, EUROFORM T100 or TS5 separators are installed after the existing scrubber contact area. In these cases, the existing vertical flow chevron, or mesh pad eliminator are inadequate due to clogging, uneven gas distribution, droplet size range too small, or liquid load too high.

Vertical and horizontal types

Venturi with TS5 Mist Eliminator
T271
T8
MUNTERS PLASdek® or METAdek absorption media — T8 or T271 separators with sprays

Here, a venturi is being utilized in conjunction with EUROFORM TS5 or T100 eliminators. This is followed by chemical absorption as the second step. The chemical absorption is accomplished by using MUNTERS PLASdek or METAdek packing and T8/T271 eliminators with sprays. The arrangement is ideally suited for those applications where plugging and scaling are potential problems, for example: limestone scrubbing of SO_2, lime scrubbing and fertilizer processing.

Vertical flow for scrubber stack



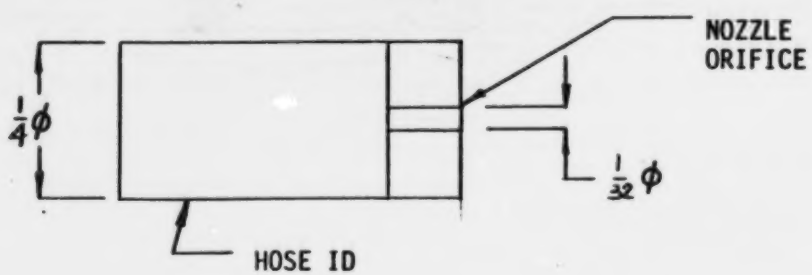
Flange-to-flange installations provide trouble-free operation in eliminating both scrubber entrainment and condensate droplets from the walls of the stacks.

FIGURE 10

Appendix 1

CALCULATION TO DETERMINE WATER SUPPLY PRESSURE

Canmet sketches of possible nozzle configurations specified orifice diameters of 1/32". The smallest diameter standard rubber hose used on mining machines is 1/4" ID. Along with the specified flowrate of 1.5 g.p.m., these three values were used to determine water supply system pressure.



$$\frac{P_1}{\gamma_1} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma_2} + \frac{V_2^2}{2g}$$ (Bernouli's Equation) -----1

$$Z_1 = Z_2$$

From the continuity equation

$$Q_1 = Q_2 \quad \text{and} \quad V_1A_1 = V_2A_2$$ -----2

$$\therefore \quad V_2 = \frac{V_1A_1}{A_2}$$ -----3

$$\frac{A_1}{A_2} = \frac{\pi(1/8)^2}{\pi(1/64)^2} = 64$$ -----4

$\therefore$ substituting into equation 3

$$V_2 = V_1(64)$$ -----5

Appendix 1

CALCULATION TO DETERMINE WATER SUPPLY PRESSURE (continued)

Referring to equation 1

$$\frac{P_1}{\gamma_1} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma_2} + \frac{V_2^2}{2G} \qquad \text{-----1}$$

$$V_1 = 1.5\ \frac{gal}{min} \times \frac{0.133\ ft^3}{gal} \times \frac{1}{\pi(1/8)^2/144} \times \frac{1}{4} \times \frac{1}{60} \qquad \text{-----6}$$

$V_1 = 2.43$ ft/sec

$P_1 = ?$

$\gamma_1 = \gamma_2 = 62.5$ lb/ft^3(water)

$P_2 = 14.7$ p.s.i. (assumed since gas flow characteristics inside venturi scrubber are unknown)

$V_2 = 64V_1$

$\therefore$ substituting into equation 1

$$\frac{P_1(144)}{62.4} + \frac{(2.43)^2}{2(32.2)} = \frac{14.7(144)}{62.4} + \frac{(64(2.43))^2}{2(32.2)} \qquad \text{-----7}$$

$$2.305\ P_1 + 0.09 + 375.56 \qquad \text{-----8}$$

$$\therefore\ P_1 = 177.61 \text{ p.s.i.} \qquad \text{-----9}$$

Therefore, the necessary pumping pressure is 177.61 p.s.i.

POOR

QUALITY

ORIGINAL